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DRAWINGS ATTACHED

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(54) IMPROVEMENTS IN OR RELATING TO MEMBRANE DESTRUCTION IN FOAMED CELLULAR MATERIAL

(71) We, TENNECO CHEMICALS, INC., of 280 Park Avenue, New York, New York 10017, United States of America, a corporation organised and existing under the laws of the State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to flexible cellular

creases in the membrane planes between mutually adjoining cells. As the reaction material solidifies, therefore an inter-connected three-dimensional cellular network is produced comprising a skeletal system of randomly-oriented and interconnected thicker strands forming the outlines of windows across which extend thinner window-like membranes. Other flexible cellular materials for example, foamed polyethylene, polypropylene, polyvinyl chloride, silicone,

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polyisocyanates, particularly aliphatic or aromatic diisocyanates in the presence of water, pigments and catalysts, particularly amines or metallic catalysts, such as stannous octoate. In the course of the reaction, carbon dioxide gas forms bubbles so as to produce a foam from the liquified reaction mixture. Often, the effect of the carbon dioxide is enhanced by the use of an auxiliary foaming agent, for example, a halogenated hydrocarbon. The mixture solidifies in the foamed state so as to produce a foamed cellular material. The gas bubbles which form in the course of the foaming process are each initially surrounded by a film of reaction mixture of generally uniform thickness. However, where the bubbles touch, the film thickness increases along the lines of contact

terial actually can be increased by removing the membrane material from the cells.

Past attempts to remove membranes from foamed cellular materials have involved chemical dissolution, the use of electromagnetic energy and the use of explosive techniques. Each of these approaches has associated difficulties. The chemical dissolution process requires the material to be soaked in a dissolving agent, then in a neutralizing agent, and finally to be rinsed and dried. In addition to its complexity, this technique subjects the strands to the same dissolving agent as the membranes so that the strands themselves become weakened. The electromagnetic energy technique requires complex photoflash equipment and is extremely difficult to control.

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This invention relates to flexible cellular materials and more particularly concerns the partial or substantial destruction of cell walls or membranes of such materials to produce useful products.

While not so limited, the present invention is particularly useful in connection with the preparation of flexible polyurethane foam from which a major proportion of the cell wall membranes have been removed. Polyurethane foams are well known in the art and are readily prepared in a variety of colours and densities as foam bodies having as few as ten cells per inch to as many as one hundred or even more cells per inch. Such products are poduced, for example, by the reaction of hydroxyl-terminated polyethers or polyesters with polyisocyanates, particularly aliphatic or aromatic diisocyanates in the presence of water, pigments and catalysts, particularly amines or metallic catalysts, such as stannous octoate. In the course of the reaction, carbon dioxide gas forms bubbles so as to produce a foam from the liquified reaction mixture. Often, the effect of the carbon dioxide is enhanced by the use of an auxiliary foaming agent, for example, a halogenated hydrocarbon. The mixture solidifies in the foamed state so as to produce a foamed cellular material. The gas bubbles which form in the course of the foaming process are each initially surrounded by a film of reaction mixture of generally uniform thickness. However, where the bubbles touch, the film thickness increases along the lines of contact and decreases in the membrane planes between mutually adjoining cells. As the reaction material solidifies, therefore an inter-connected three-dimensional cellular network is produced comprising a skeletal system of randomly-oriented and interconnected thicker strands forming the outlines of windows across which extend thinner window-like membranes. Other flexible cellular materials for example, foamed polyethylene, polypropylene, polyvinyl chloride, silicone, neoprene and rubber latex, may also be formed by known procedures to produce similar structural arrangements. These products are also susceptible to use in the process of the invention.

It has been found desirable for some purposes to eliminate, to a certain extent, the membranes which extend across the windows defined by the interconnected strands. When these membranes are removed, the material has a soften feel and appearance and is made more porous. In addition, the surface sheen in substantially eliminated, which is desirable for example, when the product is used in bonded textile clothing applications. It also has been found that the tensile strength of the material actually can be increased by removing the membrane material from the cells.

Past attempts to remove membranes from foamed cellular materials have involved chemical dissolution, the use of electromagnetic energy and the use of explosive techniques. Each of these approaches has associated difficulties. The chemical dissolution process requires the material to be soaked in a dissolving agent, then in a neutralizing agent, and finally to be rinsed and dried. In addition to its complexity, this technique subjects the strands to the same dissolving agent as the membranes so that the strands themselves become weakened. The electromagnetic energy technique requires complex photoflash equipment and is extremely difficult to control. Moreover, the orientation of the

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membranes, being defined by the random positions of the strands, prevents them from being equally exposed to the radiation source. The explosion process is also difficult to control and may be a safety hazard.

The present invention avoids the above-noted difficulties of the prior art and makes possible the formation of an open-celled flexible cellular material in a continuous, relatively simple and easily controlled process.

According to one aspect, the present invention provides a method of rupturing membranes from a sheet of flexible foamed cellular material, which comprises supporting the sheet on one side while subjecting the sheet to the action of a high velocity jet of fluid directed against the other side of the sheet.

In accordance with a preferred feature of the method of the invention, the sheet is stretched in a manner tending to reorientate the membranes toward mutually parallel planes and is subjected to the action of the jet of fluid, while the membranes are so reorientated. As a result, the membrane-destroying energy of the high velocity jet of fluid is applied most effectively, since it acts upon the major portion of the window membranes transversely thereto.

Because the cell strands are interconnected at random points, the stretching action will reorientate the planes of the window membranes in the direction of the stretch. The present invention also involves special control of the stretching action so as to provide a maximum projected surface area of the reoriented window membranes in the plane of stretch. This special control can be achieved by exerting stretching or tensile forces on the foamed material; biaxial stretching, that is, where the stretching forces are applied simultaneously or sequentially in two mutually orthogonal directions, is preferred and the forces are preferably so maintained during subsequent treatment steps. These stretch directions lie in a plane transverse to the direction of energy application. As illustratively embodied, this application of tensile forces in two directions is obtained in a continuous process by causing a sheet of flexible foamed cellular material to pass longitudinally through a tenter frame where its edges are gripped and pulled laterally. At the same time, each unit area of the foamed cellular material in the tenter frame moves longitudinally at about the same speed. This results in a stretching in two directions in the plane of the sheet, so that most of the cell window membranes become tilted into planes substantially parallel to the plane of the sheet, without the area of the cell window being significantly reduced. The momentum of the rapidly-moving fluid is sufficient to produce a mechanical rupture of the window membranes. An especially favourable action appears to take place when a high velocity fluid jet is directed against a flexible foamed material. It appears that the jet actually produces stretching in the individual cell windows, thereby rapidly stressing them to a point where they are ruptured. In carrying out the method of the invention, the sheet is preferably stretched by 10% to 50% in one direction.

According to another aspect of the invention, an apparatus is provided for rupturing membranes from flexible foamed cellular material, comprising a conveyor constructed and arranged to move a web of the flexible foamed cellular material continuously in a longitudinal direction along a given path, a backing roll interposed in the path in a position such that the web contacts the surface of the roll while passing over it during its longitudinal movement and at least one jetting nozzle directed at the surface of the roll and arranged to receive a fluid under pressure for passage through the nozzle and against the web passing over the backing roll.

In a preferred embodiment of the apparatus of the invention, the jetting nozzle(s) communicate with a liquid supply source and drying arrangements are located downstream of the jetting nozzle(s).

These drying arrangements desirably include squeeze rolls arranged to squeeze liquid out of the web. They also desirably include a hot gas jetting nozzle arranged to jet hot gas at the web downstream of the squeeze rolls. In an alternative arrangement, a drying oven is arranged downstream of the squeeze rolls, through which the web is directed.

This invention also embraces the products of the method, namely flexible foamed cellular webs which have been produced from cellular material by operation of the method of the invention.

A specific embodiment of the invention has been chosen for purposes of illustration and description, and is shown in the accompanying drawings, wherein:

Fig. 1 is a side elevational view, showing, in general outline, a processing assembly for membrane elimination in flexible foamed cellular sheets according to the present invention;

Fig. 2 is an enlarged top plan view of a sheet stretching unit forming one portion of the assembly of Fig. 1;

Fig. 3 is an enlarged perspective view of a fragment of a flexible foamed cellular sheet being processed on the assembly of Fig. 1;

Fig. 4 is an enlarged perspective view of a typical cell of the sheet of Fig. 3 before

membrane elimination according to the present invention;

Fig. 5 is an enlarged perspective view similar to Fig. 4, but showing the cell after membrane elimination according to the present invention;

Fig. 6 is an enlarged view of the fragment of Fig. 3 showing its cellular arrangement in a normal unstressed condition;

Fig. 6*A* is a magnified view of the fragment of Fig. 6 showing its cellular configuration;

Fig. 6*B* is a stylized representation of a cell in the fragment of Fig. 6;

Fig. 7 is a view similar to Fig. 6 showing the fragment stretched in one direction;

Fig. 7A is a view similar to Fig. 6A illustrating the effect of single direction stretching on the cellular arrangement;

Fig. 7*B* is a stylized representation of a cell in the fragment of Fig. 7;

Fig. 8 is a view similar to Fig. 7, but showing the fragment stretched in two directions;

Fig. 8*A* is a view similar to Fig. 7*A*, illustrating the effect of bi-directional stretching on the cellular arrangement;

Fig. 8*B* is a stylized representation of a cell in the fragment of Fig. 8;

Fig. 9 is an enlarged perspective view illustrating a membrane destruction unit employed in the assembly of Fig. 1;

Fig. 10 is a fragmentary sectional view taken along the line 10—10 of Fig. 9 and showing a jetting unit forming a portion thereof;

Fig. 11 shows a detail of Fig. 10 on an enlarged scale.

Flexible foamed cellular material to be processed in the assembly of Fig. 1 is withdrawn from a supply roll 22 in the form of a continuous web 24. The web 24 is pulled from the roll 22 and under a guide roll 26 at substantially constant speed by means of drive rolls 28. External drive means (not shown), such as electrical motors, control the driving action of the drive rolls 28.

The web 24 then passes through a tenter frame assembly 30, where it becomes stretched in a manner to be described more fully hereinafter. A pinch roll assembly 32 is located at the downstream end of the tenter frame assembly 30 to maintain lateral and longitudinal tension in the web 24. The web 24, while still in a stretched condition, passes through a membrane destruction unit 34 where the web is subjected to an energetic fluid jet which ruptures the window membrane in the web cells and converts the web to a porous open-celled structure. In the illustrative embodiment, the membrane destruction unit 34 employs the kinetic energy of a fluid jet to achieve membrane destruction.

Beyond the membrane destruction unit 34, the web 24 is allowed to relax to its normal unstretched condition. It is then passed through various other processing units 40, as may be required. For example, if the fluid jet includes a liquid, the further processing units may include liquid removal or drying devices. The web 24 is then withdrawn, as by a take-up roll 52.

The construction and operation of the tenter assembly 30 is best seen in Fig. 2. The web 24 enters the assembly 30 at a first width A and, in the assembly 30, the web is stretched laterally by means of tenter frame 54 between the drive rolls 28 and the pinch roll assembly 32, so that it leaves at a greater width *B*.

The tenter frame 54 comprises a pair of endless loop belts 56 each of which extends around upstream and downstream pulleys 58 and 60 alongside the opposite edges of the web. The pulleys 58 and 60 are mounted on associated laterally-adjustable pulley frames 62 and 64 in any convenient manner, so that they may be positioned to accommodate different web widths and to produce different degrees of lateral web stretch. Intermediate laterally-adjustable frames 66 and 68 may be positioned along the belts 56 to control the stretching pattern produced by the belts.

The belts 56 are provided with closely-spaced grippers 70 which, when the belt comes into contact with the web 24, grasp the edges of the web. The belts 56 are driven to move longitudinally in synchronism with the web 24, since the belts are secured by the grippers 70 to the edges of the web, they stretch it laterally during such movement. The grippers 70 are released from the belt when they reach the downstream pulleys 60.

The stretching action produced by the tenter assembly 30 is biaxial, that is, it applies tensile stresses in two mutually-orthogonal directions, i.e., longitudinally and laterally of the web 24. When a sheet of flexible material is stretched along one direction only (e.g., longitudinally) it will, if otherwise unrestrained, contract in an orthogonal direction (i.e., laterally). When the contraction in the orthogonal direction is prevented by restraint, the sheet will experience a stretching tension in these two directions or dimensions.

In the present case, the biaxial two-dimensional stretching tension is produced on a continuous basis by controlling the belts 56 so that they maintain the web length essentially constant, while they pull laterally on the edges of the web. As a result, stretching is produced in two orthogonal directions, i.e., longitudinally and laterally

in the plane of the web 24. Normally, the pull rolls 28 and the belts 56 will operate at the same speed, so that (on a continuous web movement basis) the web is held to a fixed length while it is stretched in width. This results in an actual stretch of the web in both length and width because, if the length were left unrestrained, the web would contract longitudinally when stretched laterally. Of course, in principle, the web could be held to a fixed width while being stretched in length, thereby also producing a biaxial or two-dimensional stretch. Also, additional longitudinal stretch may be achieved by moving the belts 56 at a greater speed than the pull rolls 28. The manner in which two-dimensional stretching contributes to improved membrane elimination can be seen from the diagrammatic representations of Figs. 3—8. Fig. 3 illustrates a fragment 78 of foamed cellular material in sheet form, which may, for example, be part of the web 24. The web fragment 78 has a thickness (*t*) considerably less than its width (*w*) and length (*l*). Superficially, it resembles a sheet of stretchable fabric or rubber. However, closer examination reveals that it is made up of minute closely-packed cells.

The width and length of the fragment 78 define its plane of extent and the plane of the web 24 in which the fragment 78 lies. An arrow E in Fig. 3 represents the direction of energy flow incident on the fragment 78 when membrane elimination is carried out. As can be seen, the direction of incident energy E is transverse to the plane of the fragment 78. Less efficient energy attack on the windows occurs when the plane of the membrane is inclined with respect to its direction of energy.

Figs. 4 and 5 illustrate a typical cell 80 formed in the web fragment 78 of Fig. 3. As shown in Fig. 4, the cell 80 is made up of a number of strands 82 in generally random arrangement but interconnected at various locations or nexuses 84. The interconnecting of the various randomly positioned strands 82 defines window-like openings across which are stretched window membranes 86. When membranes cover windows on all sides of the cell 80, it is referred to as a "closed" cell; the air or gas entrapped within the cell will contribute to a certain stiffness and resilience characteristic in the foamed cellular material containing the cell. The window membranes 86 also render the foamed cellular material impervious to fluids such as air or water; also, they result in a stiffness and sheen which is undesirable for many uses.

Fig. 5 shows the structure of the cell 80 with the window membranes 86 destroyed. As can be seen, the cell 80 in Fig. 5 consists only of the strands 82 arranged as in Fig. 4 and interconnected at the nexuses 84. These strands have hanging therefrom remnants or ragged edges 87 of the now ruptured window membranes.

As can be seen in Fig. 4, the window membranes 86, whose orientation is individually defined by the positions and angles of the various strands 82 to which they are attached, lie in a multiplicity of different planes only some of which are transverse to the arrow *E*. Thus, membrane elimination energy impingent upon a cell in a single direction cannot be expected to be completely effective on more than a small percentage of cell membranes, namely, those which happen to lie in planes transverse to the direction *E* of incident energy.

Figs. 6, 7 and 8 show magnified portions of the web fragment 78 of Fig. 3 as the fragment is subjected to different tensile or stretching forces. In these drawings, a first arrow *L* indicates the direction of web movement longitudinally in the processing apparatus. Other arrows *W* indicate the width or lateral direction across the web; and a further arrow E indicates the direction of application of membrane destroying energy. The dimensions of the web fragment in the *L*, *W* and *E* directions are indicated by the corresponding letters *l*, *w* and *t*. As can be seen, in Fig. 6, the web fragment 78 is essentially unstretched and the various cells 80 which make up the fragment are in their normal configuration. This cellular arrangement is better seen in the highly magnified view of Fig. 6A. The various strands 82 extend randomly throughout the fragment while intersecting at the nexuses 84 which also extend randomly throughout the fragment. The various cell members 86 are also randomly orientated as described in connection with Fig. 4. The general configuration of a typical untensioned cell in the fragment 78 of Fig. 6 is represented in the stylized presentation of Fig. 6B as a sphere 90. As can be seen, only a relatively small portion of the sphere can be considered as substantially transverse to the direction E of incident energy.

In Fig. 7, the fragment 78 has been subjected to tensile forces T_w tending to stretch it in a lateral direction across its width, and extending its width from (*w*) to (w^1). In this case, the length (*l*) of the fragment is unrestrained and free of tensile forces. As a result, it will tend to pull inwardly and will decrease to (l^1). The effect in this case can be seen in the highly magnified view of Fig. 7A wherein the cells 80 are elongated in one direction but are narrowed in the other direction. The membranes 86 are tilted toward the plane of the fragment 78 but they become narrowed so that their total surface area transverse to the applied energy E is not substantially increased.

The ability for this stretching and change in configuration to occur is in some part due to the elasticity of the strands 82, but in greater part it is due to the random arrangement of the nexus 84. The strands 82 tend to transmit tensile forces along their length. Now the adjacent strands are not axially aligned, but rather they are connected to each other via a path which appears kinked or crinkled. Thus, a tensile force in a given direction tends to straighten out the crinkles and deform the cells to an elongated configuration. This elongated configuration is represented in the stylized presentation of Fig. 7B as a cigar shape 92. Again, as can be seen, even though the sphere shape 90 (Fig. 6B) is converted by longitudinad tension or stretching to a cigar shape 92 (Fig. 7B), the effect of such stretching on the amount of cell surface which is transverse to the direction E of incident energy, is minor.

In Fig. 8, the fragment 78 is subjected to tensile forces $T_{(l)}$ and $T_{(w)}$ tending to stretch it both longitudinally and laterally. This is done by maintaining the initial longitudinal dimension (l) while increasing the lateral dimension (w) to (w^1). The effect of this is seen in the magnified view of Fig. 8A wherein the cells 80 are shown stretched out in the plane of the fragment 78 with their membranes 86 substantially totally lying in a direction transverse to the direction E of applied energy. This cell reshaping is represented in the stylized presentation of Fig. 8B as a pancake or disc-shape 94. It will be appreciated that nearly the entire surface area of the shape 94 is transverse to the direction E of incident energy so that this energy is utilized on the material of the fragment 78 with maximum effectiveness.

It will be appreciated that the principle of stretching to reorientate cell window membranes as disclosed herein is useful for improving window membrane destruction efficiency with nearly any type of directable energy. For example, some forms of electromagnetic radiant energy can be focused on to the web 24 to produce cell window membrane destruction; the stretching action disclosed herein will improve the effectiveness of such process, since it will reorient the window membranes so that they face the energy source. To the extent that other forms of directable energy, for example, light or accoustical energy can be used to destroy or rupture window membranes, the stretching concepts of the present invention can be used advantageously.

In the illustrative embodiment of the present invention, there is employed a novel window membrane destroying means, namely, a high velocity fluid jet. It has been discovered that such jet, when directed at the web, will effectively rupture cell membranes without adversely affecting cell strands and that an efficient and controllable membrane removal operation can be carried out in this manner.

The membrane destruction unit is best seen in the enlarged perspective view of Fig. 9. As can be seen, the web 24 passes through the pinch roll assembly 32 and over a backing roll 100. The friction between the backing roll 100 and the web 24 serves to maintain the stretch imposed on the web by the tenter assembly. Thereafter, as shown in Fig. 2, the web reverts to its normal original width *A*. A jetting nozzle unit 102 is directed down upon the web 24 as it passes over the backing roll 100. Fluid, such as water or air, is supplied under high pressure from an external source (not shown) to the nozzle unit 102 via an inlet conduit 104. As can be seen, the nozzle unit 102 extends across the entire width of the web 24 over the backing roll 100.

Fig. 10 illustrates the operation of the jetting nozzle unit 102. As can be seen, the unit includes an interior compartment 106 wherein fluid under pressure accumulates for even distribution across the width of the web 24. A nozzle opening 108 extends out from the compartment 106 along the length of the unit. This nozzle opening, as shown in Fig. 10, is directed against the portion of the web 24 overlying the backing roll 100. The nozzle unit 102 converts the pressure energy of the fluid contained therein to kinetic energy of high velocity flow of the fluid as it passes out the nozzle opening 108. The amount of energy delivered by the unit depends upon both the velocity of flow of the fluid through the nozzle opening and upon the density of the fluid. Liquids, of course, have far greater density than gases, and for greater energy flow liquids are preferred over gases. In addition, since liquids are incompressible, much more efficient pumping can be achieved with liquids than with gases.

In certain instances, however, gases may be more advantageous than liquids for membrane destruction. Gases which are essentially dry may be used thereby avoiding the problem of drying the web after the membrane destroying operation. In addition, gases can usually be heated to a higher temperature than liquids. This can be of help in destroying the membranes of materials such as polyurethane foam since the use of hot gases will materially weaken the membranes thereby enabling the force of the gases to be more effective in breaking through them. It has been found that gas temperatures up to 450°F. can be employed without causing discoloration of the web material and without melting it.

Fig. 11 illustrates the action of fluid flow in obtaining membrane destruction of a web

of foamed cellular material lying over a backing roll such as the roll 100. It would normally be expected that the blast of liquid or gas would, upon impinging the web 24, merely flatten it against the backing surface and hold it there without destroying the membranes. However, it has been found that this is not the case and, in fact, a very effective membrane destruction can be obtained in this manner.

It is believed that what happens is that a high velocity jet will, as shown in Fig. 11, force the jetted fluid down between the backing surface (i.e., the roll 100) and the web 24 so that the only escape for the fluid is back again through the fluid. This rebound effect is illustrated in Fig. 11 by lines 120 representing incident fluid flow and lines 122 representing rebound flow. These two flows cooperate to apply opposite but not collinearly directed forces against the foamed cellular material; and this serves to rupture the cell membranes without producing undue stress on the cell strands.

The roll 100 should have sufficient strength to hold the web 24 against the jetting action, and at the same time it should have a certain degree of flexibility to accommodate a continuous fluid flow through the web. Also, as indicated above, the roll should be able by friction to hold the web in stretched condition as it passes under the jetting nozzle unit 102. The roll surface may be rubber having a durometer rating in the range of 7 to 20. Also, foamed polyurethane material has been found to be quite effective for this purpose.

The following are some typical examples of conditions according to which the present invention has been carried out.

Example 1

An 0.06 inch thick web of foamed flexible polyurethane material was subjected to the action of a water jet while lying unstretched over a backing roll having a 7 durometer rubber surface. The water jet opening was 0.008 inches in width and the water pressure was 95 psi. The web was passed by the jet at a rate of approximately 250 lineal feet per minute. This produced approximately 90% membrane destruction on the jet facing side of the web and about 87% on the reverse side.

The degree of membrane destruction is ascertained visually by stretching the web material and noting the effect of such stretching on lustre or light reflectivity. Where the reflectivity is low, the degree of membrane destruction is high. Other methods which may be used for measuring the degree of membrane destruction include measurment of the pressure drop across the material at a given gas flow rate and using a microscope to count the membranes present in a given segment.

Example 2

A pair of 0.06 inch thick specimens of foamed flexible polyurethane material were superimposed and together subjected to the action of a water jet while in stretched condition. The specimens were stretched in one direction by 45% while restrained against corresponding contraction in the orthogonal direction. The specimens were passed over a 20 durometer rubber backing roll at about 100 lineal feet per minute while water at 82 psi was jetted from a 0.010 inch wide opening. This produced a 98% membrane destruction on the jet facing side of the upper layer, 95% on the two mutually facing sides of the two layers and 90% on the reverse side of the lower layer.

Example 3

An 0.06 inch thick web of foamed, flexible polyurethane material was subjected to the action of a heated air jet passing through a 0.006 convergent opening at about 50 psi. The web was stretched in one direction by 45% while restrained against corresponding contraction in the orthogonal direction. The specimen was passed over a 20 durometer rubber backing roll at about 150 lineal feet per minute during the jetting and was thereafter inverted and again subjected to the jetting action.

This process was repeated for two separate specimens. In one case, the air temperature was 336°F and the degree of membrane destruction was 85%. In the other cases, the air temperature was 452°F and the degree of membrane destruction was 95%.

In each of the three examples given, the polyurethane material had a density of 1.75—1.80 lbs/cu.ft. and a cell count of about 65—75 per inch. However, the invention is similarly useful with foamed materials having a density of 1 to 3.5 lbs cu.ft. and a cell count from 10 to 100 per inch. Also, the nozzle to web distance in each example was varied from 1/[illegible] to [illegible] inch with substantially similar results.

It will be appreciated that variations may be made in the degree of stretch of the web, as well as the temperature and pressure of the fluid being jetted. These will, to a greater or lesser degree, affect the amount of membrane destruction. Thus, in Example 3, the percentage of membrane destruction increased with the temperature of the jetted air. Similarly, a reduction in the lineal speed of web movement also will result in an increase in percentage of membrane destruction.

In general, however, good results with a water jet have been obtained with a lineal web speed of 200—250 feet per minute

while water at about 50—100 psi was sprayed through a 0.008—0.010 inches wide nozzle opening at a distance of about $^{1}/_{20}$—$^{3}/_{32}$ inch from the web while the web was stretched in both directions by about 50%. Liquids other than water may be used. In fact, the invention can be practiced with nearly any inert, volatile liquid which will not produce swelling of the material. Also, the liquid may, but need not, be non-flammable, depending upon safety considerations.

Good results were also obtained with a hot air jet with a lineal web speed of 100—250 feet per minute while air at a temperature of 300—450°F maintained at a pressure of about 50—100 psi was jetted through a 0.006—0.10 inches wide nozzle opening also about $^{1}/_{20}$—$^{3}/_{32}$ inch from the web while the web was stretched by about 50%. Other gases may also be used, for example, nitrogen, water vapour (steam) and carbon dioxide.

The present invention is useful in removal of membranes from flexible polyurethane webs having thicknesses of from 0.010 to 0.100 inches; thicker webs can be subjected to effective membrane destruction by twice passing them through the apparatus with a different surface exposed to the direct action of the fluid jet on each pass.

WHAT WE CLAIM IS:—

1. A method of rupturing membranes from a sheet of flexible foamed cellular material, which comprises supporting the sheet on one side while subjecting the sheet to the action of a high velocity jet of fluid directed against the other side of the sheet.

2. A method according to claim 1, wherein the sheet is stretched in a manner tending to reorientate the membranes toward mutually parallel planes and is subjected to the action of the jet of fluid, while the membranes are so reorientated.

3. A method according to claim 2, wherein the sheet is stretched in at least one direction in a plane transverse to the direction of the jet of fluid.

4. A method according to claim 3, wherein the sheet is stretched by 10% to 50% in one direction.

5. A method according to claim 2, wherein the sheet is stretched in different directions in planes transverse to the direction of the jet of fluid.

6. A method according to claim 2, wherein the sheet is stretched in one direction while restrained from contraction in an orthogonal direction in its plane.

7. A method according to any of claims 2 to 6, wherein the material is moved in stretched condition at a rate of 100—250 lineal feet per minute under a jet of air heated to 300° to 450°F. while maintained at a pressure of 50—100 psi and jetted through an opening .006—.010 inches wide.

8. A method according to any of claims 2 to 6, wherein the material is moved in stretched condition at a rate of 200—250 lineal feet per minute under a jet of water maintained at a pressure of 50—100 psi and jetted through an opening .008—.010 inches wide.

9. A method according to any of claims 1 to 6, wherein the fluid is a gas.

10. A method according to claim 9, wherein the fluid is a hot gas.

11. A method according to claim 9 or 10, wherein the gas is air.

12. A method according to claim 10, wherein the temperature of the gas is sufficient to weaken appreciably the membranes and assist the action of the high velocity jet.

13. A method according to claim 9, 10 or 12, wherein the material is polurethane and the temperature of the gas is 300°—450°F.

14. A method according to any of claims 1 to 6, wherein the fluid is a liquid.

15. A method according to claim 14, wherein the liquid is water.

16. A method according to any preceding claim, wherein the material is supported by a semi-flexible surface on its side opposite the side exposed to the jet of fluid.

17. A method according to claim 1, substantially as herein described.

18. A flexible, foamed, cellular web, when produced by a method according to any of claims 1 to 17.

19. An apparatus for rupturing membranes from flexible foamed cellular material, comprising a conveyor constructed and arranged to move a web of the flexible foamed cellular material continuously in a longitudinal direction along a given path, a backing roll interposed in the path in a position such that the web contacts the surface of the roll while passing over it during its longitudinal movement and at least one jetting nozzle directed at the surface of the roll and arranged to receive a fluid under pressure for passing through the nozzle and against the web passing over the backing roll.

20. An apparatus according to claim 19, wherein the conveyor is arranged upstream of the jetting nozzle(s) to effect a stretching of the web in its plane and to maintain the stretch in the portion of the web passing by the jetting nozzle(s).

21. An apparatus according to claim 19 or 20, wherein the jetting nozzle is elongated in a direction transverse to and extends across the conveyor.

22. An apparatus according to claim 19, 20 or 21, wherein the jetting nozzle(s) communicate with a liquid supply source and wherein drying arrangements are located downstream of the jetting nozzle(s).

23. An apparatus according to claim 22, wherein the drying arrangements include squeeze rolls arranged to squeeze liquid out of the web.

24. An apparatus according to claim 23, wherein the drying arrangements include a hot gas jetting nozzle arranged to jet hot gas at the web downstream of the squeeze rolls.

25. An apparatus according to claim 23, wherein the drying arrangements include a drying oven arranged downstream of the squeeze rolls, through which the web is directed.

26. An apparatus according to claim 19, substantially as described with reference to the accompanying drawings.

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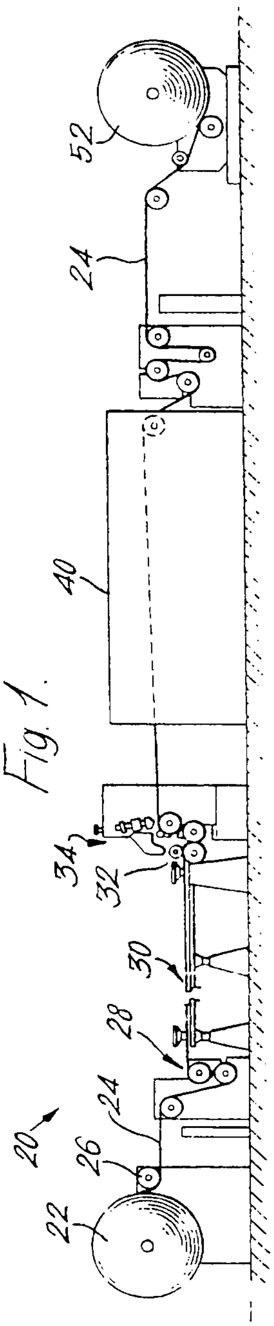


Fig. 1.

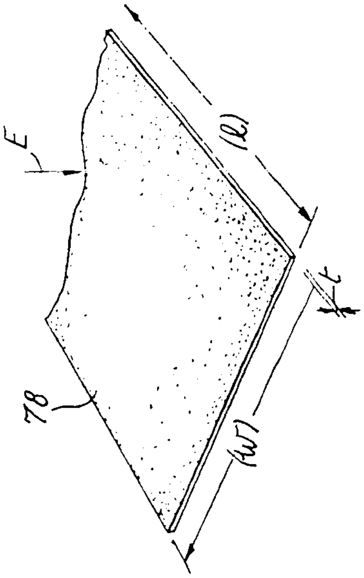


Fig. 3.

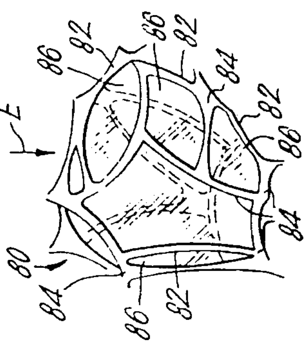


Fig. 4.

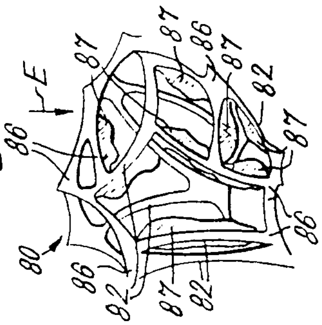


Fig. 5.

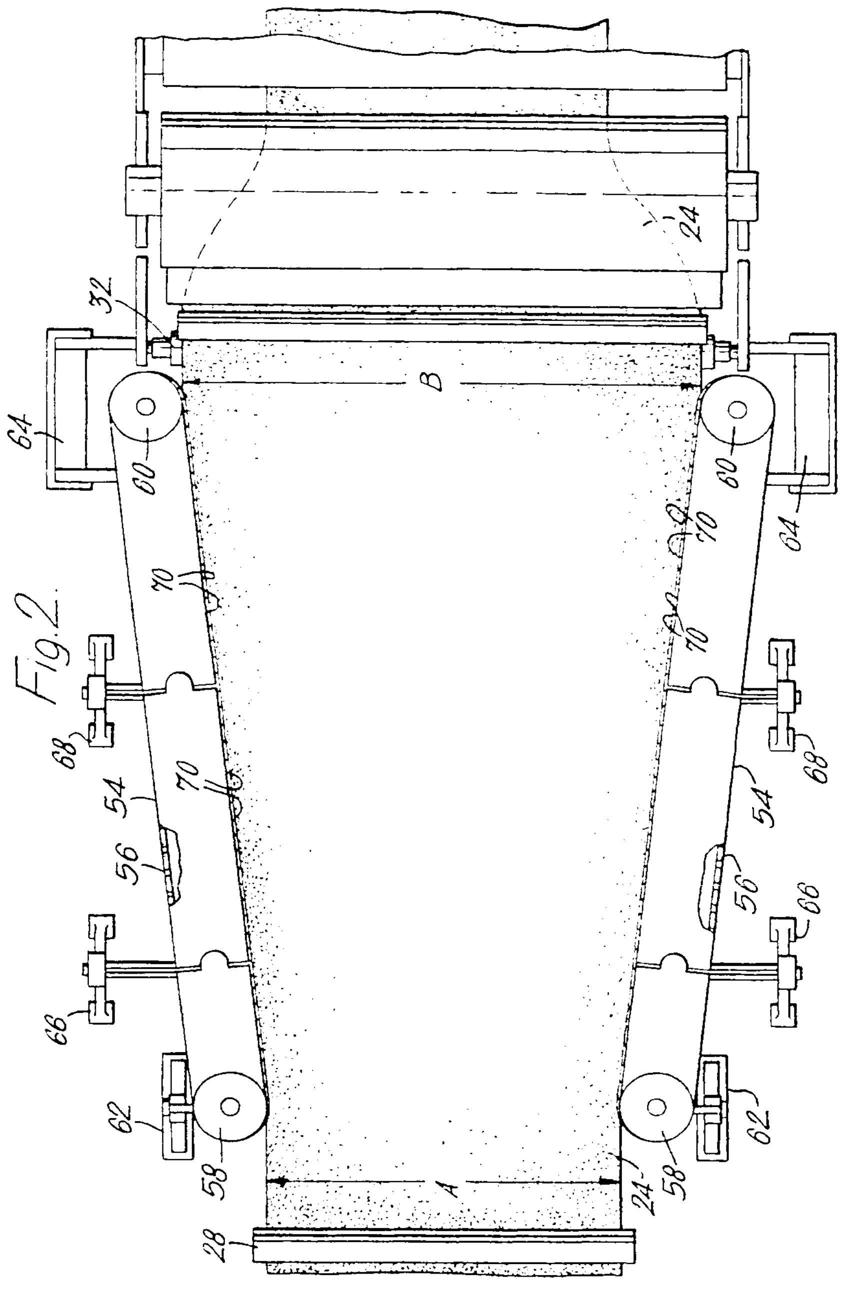


Fig.2.

Fig. 6.

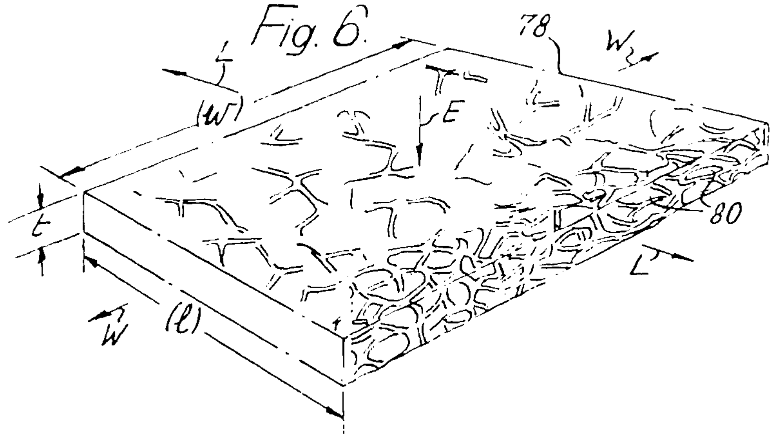


Fig. 6A.

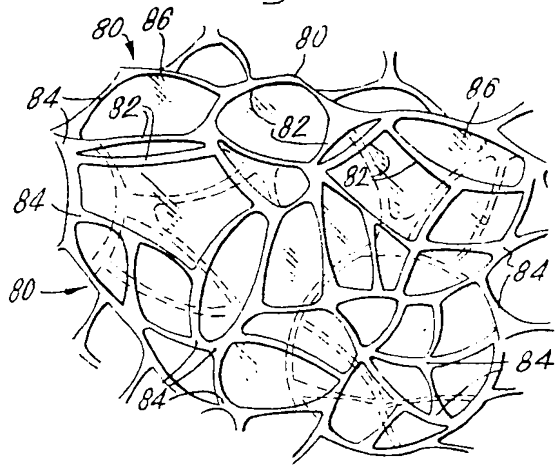


Fig 6B.

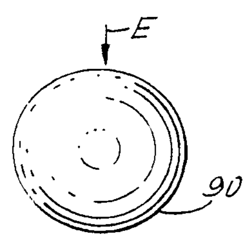


Fig 7.

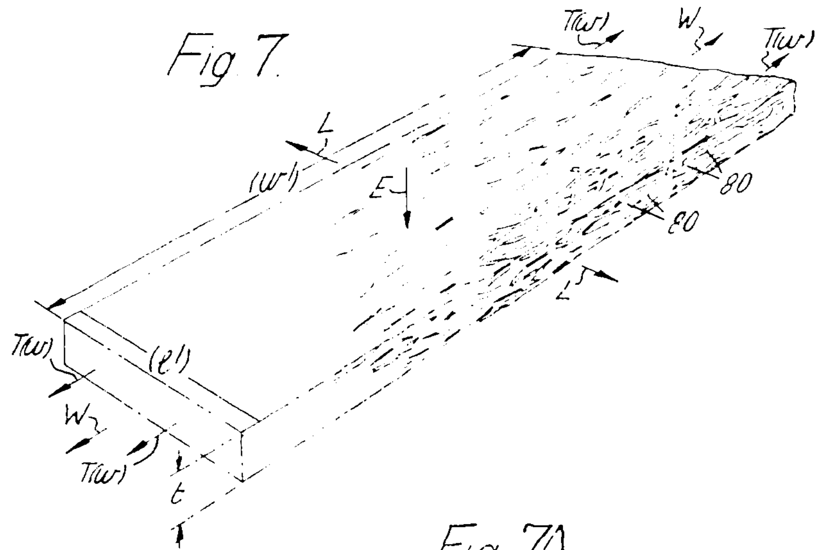


Fig. 7A.

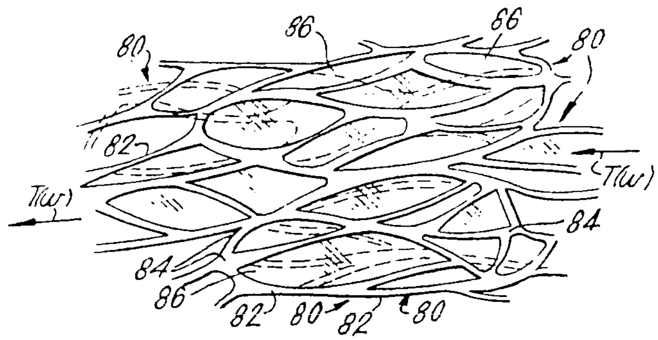


Fig. 7B.

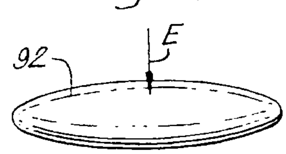


Fig.8.

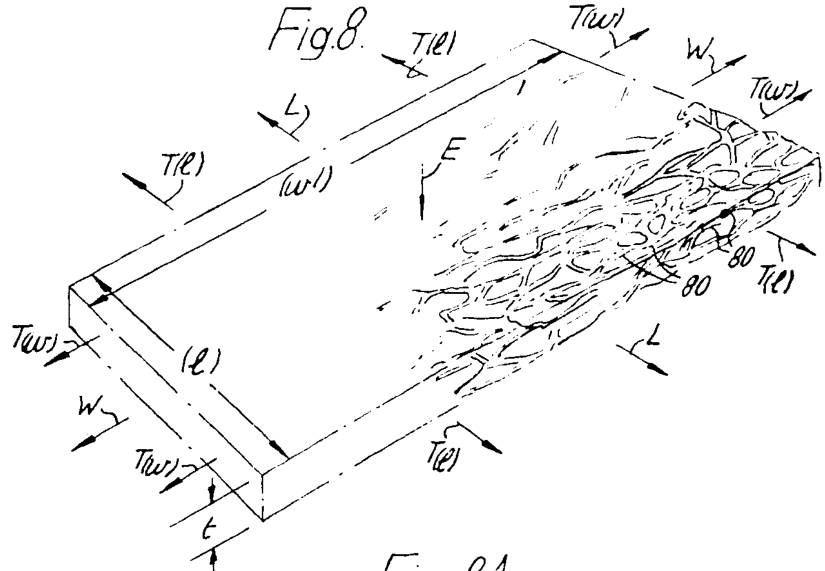


Fig.8A.

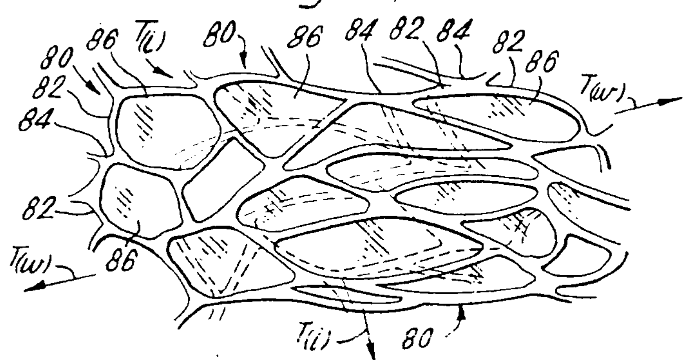


Fig.8B.

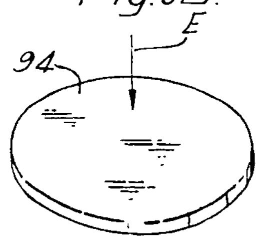
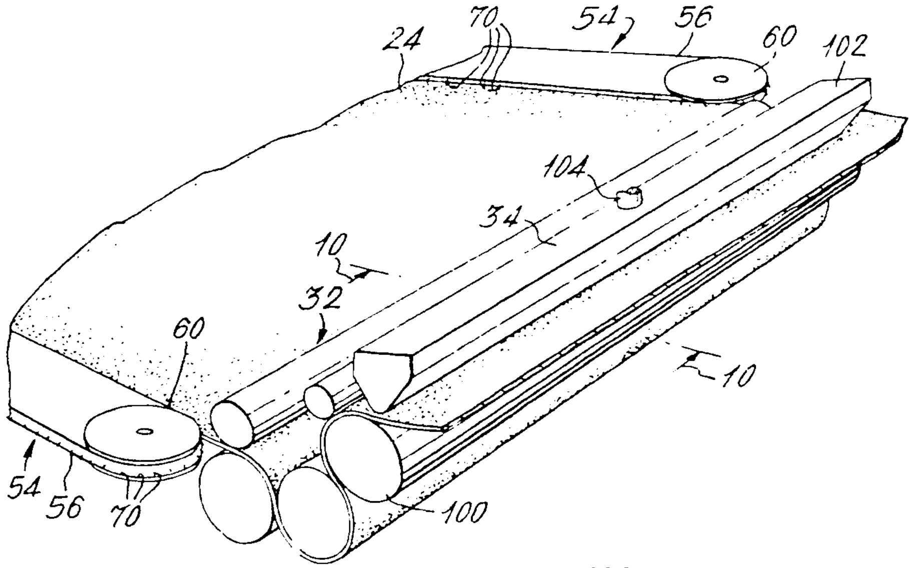


Fig. 9.



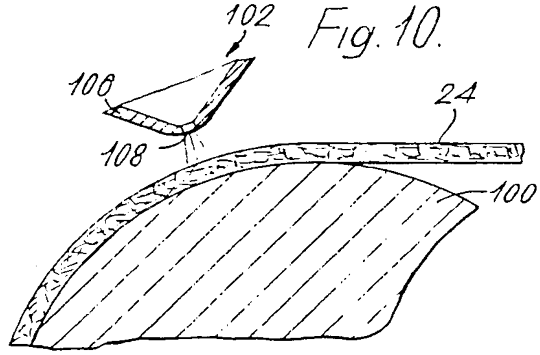


Fig. 10.

Fig. 11.